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RESEARCH MEMORANDUM

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AT TRANSONIC SPEEDS OF SYMMETRICALLY MOUNTED

NACELLES IN VARIOUS CHORDWISE POSITIONS

AT THE WING TIP OF A 45° SWEPTBACK

WING AND BODY COMBINATION

By William B. Pepper, Jr., and Sherwood Hoffman

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Langley Field, Va.

NATIONAL ADVISORY COMMITTEE

FOR AERONAUTICS

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SUMMARY

The effect on drag of varying the chordwise position of a nacelle
at the wing tip of a 45° sweptback wing and body combination has been
determined through transonic flight tests at zero lift. The wing had
a sweepback angle of 45° along the quarter-chord line, an aspect ratio
of 6.0, a taper ratio of 0.6, and an NACA 65A009 airfoil section in
the free-stream direction. The nacelle and fuselage fineness ratios
were 9.66 and 10.0, respectively.

The drag of the configuration with nacelles located in the rear
chordwise positions was either equal to or less than the drag of the
configuration without nacelles over most of the speed range. The drag
of the configuration with nacelles located in the forward chordwise
position was about the same as that of the basic configuration up to a
Mach number of 1.1. The lowest nacelle drag was obtained from the
nacelle mounted in the rear chordwise position at Mach numbers from
0.99 to 1.20. The force-break Mach numbers of the models with nacelles
were approximately equal to the force-break Mach number of 0.96 for the
basic configuration.

INTRODUCTION

As part of a general transonic research program of the National
Advisory Committee for Aeronautics to investigate the aerodynamic

properties of promising aircraft configurations, the Langley
Pilotless Aircraft Research Division (at its testing station at Wallops
Island, Va.), has tested a number of rocket-propelled free-flight
models to determine the variations of zero-lift drag coefficient with
Mach number for a high-aspect-ratio wing and body configuration with
solid nacelles at various positions on the wing.

Reference 1 shows the effect on drag of varying the chordwise
position of a nacelle located at 40 percent of the wing semispan;
reference 2 shows the effect on drag of varying the spanwise location
of the nacelle; and, reference 3 shows the effect on drag of varying
the vertical position of the nacelle at 40 percent of the semispan.
Because of the low drag obtained when nacelles were located at the
wing tip (reference 2), especially near a Mach number of 1.0, the wing-
tip nacelle location was selected for further investigation. The
present investigation gives a comparison of the drags at zero lift
obtained for three chordwise nacelle positions at the wing tip.

The wing-body configuration (basic configuration) and the
nacelles were similar to that used in the previous tests (references 1,
2, and 3). The wing had a sweepback angle of 45° along the quarter-
chord line, an aspect ratio of 6.0, a taper ratio of 0.6, and an NACA
65A009 airfoil section in the free-stream direction. The fuselage
and nacelle fineness ratios were 10.0 and 9.66, respectively.

The nacelles were proportioned to house an axial-flow turbojet
engine with an afterburner. The basic lines of the nacelle nose were
designed to accommodate NACA 1-series inlets with critical Mach
numbers above M = 0.90.

The tests were conducted without air flow through the nacelles
to simplify the investigation. It was anticipated that, with the
introduction of internal air flow, the resulting variations of drag
with ducted-nacelle location would be similar to the variations found
for solid nacelles.

Tests covered a continuous Mach number range from 0.80 to 1.25.
The Reynolds number, based on the wing mean aerodynamic chord, varied
from 3.8×10^6 to 7.3×10^6.

SYMBOLS

a longitudinal acceleration, feet per second per second

C_D total drag coefficient, based on S_W

C_{D_N} drag coefficient for nacelle plus interference, based on S_F

c wing chord at 96 percent of the semispan, inches

e distance between nacelle inlet and wing leading edge, inches

g acceleration due to gravity, 32.2 feet per second per second

M Mach number

q free-stream dynamic pressure, pounds per square foot

R Reynolds number, based on wing mean aerodynamic chord

S_F frontal area of one nacelle, square feet

S_W total wing plan-form area, square feet

W model weight during deceleration, pounds

γ angle between flight path and horizontal, degrees

x station, inches

y ordinate, inches

MODELS

The models used for this investigation were the same as those in references 1, 2, and 3, except for the location of the nacelles. Details and dimensions of the wing-body-fin combination, the nacelles, and the nacelle positions are given in figures 1 and 2. Photographs showing the general arrangements of the models flown are presented as figure 3.

The wing had a sweepback angle of 45° along the quarter-chord line, an aspect ratio of 6.0 (based on total wing plan-form area), a taper ratio of 0.6, and an NACA 65A009 airfoil section in the

free-stream direction. The wing leading edge intersected the maximum
diameter of the fuselage. The fuselage fineness ratio was 10.0. The
ratio of total wing plan-form area to fuselage frontal area was 16.0.

Each nacelle was a solid body of revolution having an NACA
1-50-250 nose-inlet profile, a cylindrical midsection, and an afterbody
of NACA 111 proportions. The nacelle inlet was faired to a point
making the nacelle solid. The fineness ratio of the solid nacelle was
9.66.

The center lines of the nacelles were located in the wing plane
parallel to the free-stream direction at 96 percent of the semispan
in order to make the outer portion of the nacelle flush with the wing
tip. The chordwise nacelle location, measured with respect to the
distance e between the nacelle inlet and the wing leading edge, was
varied for the tests (fig. 2). The chordwise positions expressed in
percent of the wing chord c at 96 percent of the semispan were 123,
82, and 48 percent.

TESTS AND MEASUREMENTS

Three rocket-propelled zero-lift models were tested at the
Langley Pilotless Aircraft Research Station, Wallops Island, Va.
Velocity and trajectory data were obtained from the CW Doppler
velocimeter and the NACA modified SCR-584 tracking unit. A survey
of atmospheric conditions for each test was made through radiosonde
measurements from an ascending balloon.

The values of total drag coefficient, based on total wing plan-
form area, were calculated for decelerating flight (reference 1) with
the formula

$$C_D = - \frac{W}{qgS_W} (a + g \sin \gamma)$$

The variations of nacelle-plus-interference drag coefficient with
Mach number were obtained from the difference in drag coefficient of
faired C_D curves of a model without nacelles and a model with nacelles.
This coefficient, based on nacelle frontal area, is

$$C_{D_N} = \left(C_{D_{\text{nacelles on}}} - C_{D_{\text{nacelles off}}} \right) \frac{S_W}{2S_F}$$

The magnitude of the error in drag was established by testing three identical models without nacelles in reference 1 and was based on the maximum deviation found between C_D curves faired through experimental points. The error in total drag coefficient was within ±0.0004. The error in nacelle-plus-interference drag coefficient was within ±0.046 at subsonic and supersonic speeds and about ±0.1 near $M = 1.0$. The accuracy of the flight Mach number was estimated to be within ±0.005.

Flight tests of the models covered a Reynolds number range from 3.8×10^6 at $M = 0.80$ to 7.3×10^6 at $M = 1.25$ as shown on figure 4.

RESULTS AND DISCUSSION

Faired curves showing the variations of total drag coefficient with Mach number for the models tested are presented in figure 5 and are summarized in figure 6. A comparison of the C_D curves for the models shows that the drag of the configuration with nacelles at the 82- and 48-percent-chordwise positions was either equal to or less than the drag of the wing-body configuration near a Mach number 1.0. The drag of the model with nacelles at the 123-percent station was approximately the same as that of the configuration without nacelles up to $M = 1.1$. In regard to the effect of chordwise nacelle location on drag, the model with nacelles located in the rear chordwise position at the wing tip had less drag than each of the other models with nacelles between $M = 0.99$ to $M = 1.2$.

In general, the variation of drag with chordwise nacelle location at the wing tip was similar to that given in reference 1 for the chordwise nacelle locations at 40 percent semispan. Although the nacelle-plus-interference drags referred to in reference 1 were higher than those of this investigation, especially near $M = 1$, the rear nacelle positions on the wing chord also had less drag than the forward nacelle positions.

The force-break Mach numbers of the models with nacelles were approximately equal to the force-break Mach number of 0.96 of the basic configuration without nacelles.

The variations of C_{D_N} with Mach number are shown in figure 5 and are summarized in figure 6. The nacelle-plus-interference drag coefficients are compared with the drag coefficient of an isolated nacelle, which was estimated in reference 1. A comparison between the estimated isolated nacelle drag and the measured nacelle drag is indicative of the interference drag.

From a comparison of the C_{D_N} with M curves, it is evident that the low nacelle drags were due to the favorable interference that was present over the entire Mach number test range. The negative values of C_{D_N} indicate that the nacelle arrangements used herein may have improved the flow over the wing to give low drag.

CONCLUSIONS

The effect on drag of varying the chordwise location of a nacelle at the wing tip of a 45° sweptback wing and body combination has been determined through transonic flight tests at zero lift. The following effects were noted:

1. The drag of the configuration with nacelles located in the rear chordwise positions was either equal to or less than the drag of the configuration without nacelles over most of the speed range. The drag of the configuration with nacelles located in the forward chordwise position was about the same as that of the basic configuration up to a Mach number of 1.1.

2. The lowest nacelle drag was obtained from the nacelle mounted in the rear chordwise position at Mach numbers from 0.99 to 1.20. Low nacelle drags that were due to favorable interference occurred over the speed range for all the nacelle positions tested.

3. The force-break Mach numbers of the models with nacelles were approximately equal to the force-break Mach number of 0.96 of the basic configuration.

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        Langley Field, Va.

REFERENCES

1. Pepper, William B., Jr., and Hoffman, Sherwood: Transonic Flight
      Tests to Compare the Zero-Lift Drag of Underslung and Symmetrical
      Nacelles Varied Chordwise at 40 Percent Semispan of a 45° Swept-
      back, Tapered Wing. NACA RM L50G17a, 1950.

2. Pepper, William B., Jr., and Hoffman, Sherwood: Comparison of Zero-
      Lift Drags Determined by Flight Tests at Transonic Speeds of
      Symmetrically Mounted Nacelles in Various Spanwise Positions on
      a 45° Sweptback Wing and Body Combination. NACA RM L51D06, 1951.

3. Hoffman, Sherwood: Comparison of Zero-Lift Drag Determined by
      Flight Tests at Transonic Speeds of Pylon, Underslung, and
      Symmetrically Mounted Nacelles at 40 Percent Semispan of a
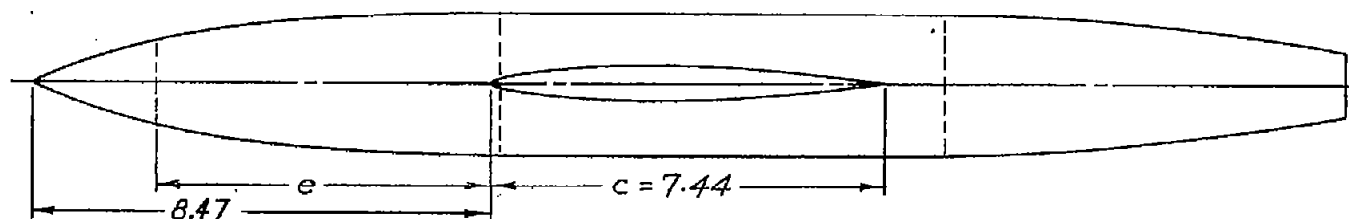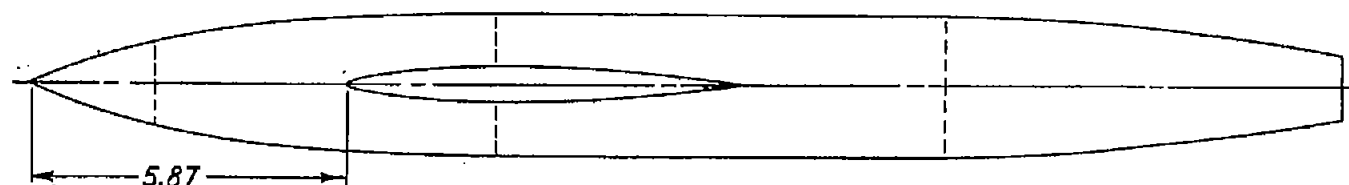   45° Sweptback Wing and Body Combination. NACA RM L51D26, 1951.

Model characteristics:
Body fineness ratio 10.0
Wing aspect ratio 6.0
Wing taper ratio 0.6
Mean aerodynamic chord, ft 0.822
Airfoil parallel to free
   stream . . . . NACA 65A009
Total wing plan-form
   area, sq ft 3.878
Exposed wing plan-form area, sq ft . . . 3.333
Exposed wing frontal area, sq ft 0.299
Body frontal area, sq ft 0.242
Total frontal area, sq ft 0.550
Exposed fin plan-form area
   (2 fins), sq ft 0.468

Fins are flat plates and 0.091 inch thick with
   0.045-inch radius at edges.

Wing L.E. intersects
body at max. diam.

Figure 1.- General arrangement and dimensions of test model. All
dimensions are in inches.

Nose plug | NACA 1-50-250 inlet (solid) | Cylindrical mid section | NACA III afterbody

2.51 diam.

1.20

2.33

8.60

11.45

16.83

24.25

(a) Model B; e/c = 1.23

8.47

e

c = 7.44

(b) Model C; e/c = 0.82

5.87
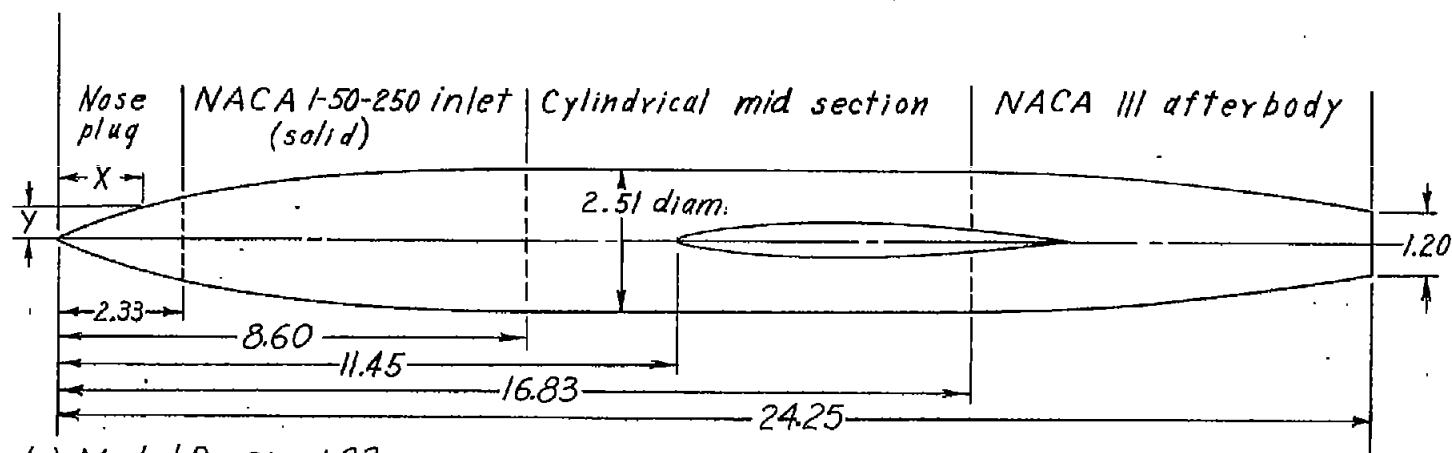
(c) Model D; e/c = 0.48

Nacelle fineness ratio = 9.66
Nacelle frontal area = 0.034 sq ft

Figure 2.- Cross-sectional views showing chordwise location of nacelles
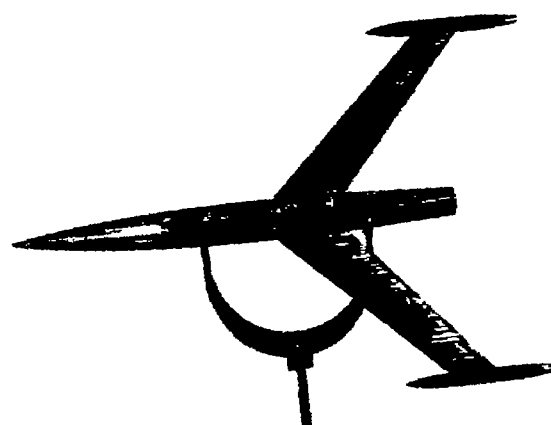mounted at 96 percent of the semispan. All dimensions are in inches.
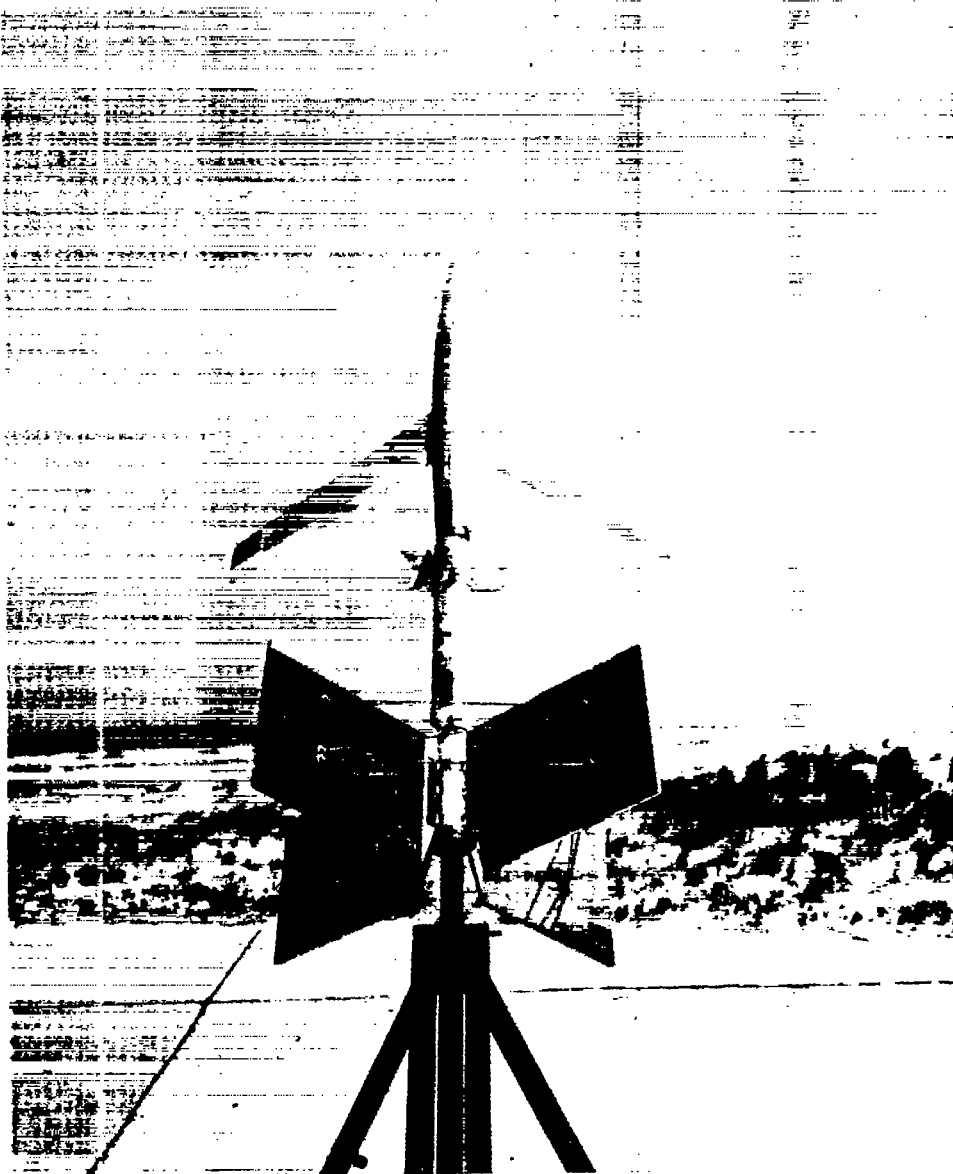
Model A

L-61049

(a) Test model without nacelles. Model and booster arrangement on rail launcher.

Figure 3.- General views of test models.

NACA RM L51F13

Model B; $\frac{e}{c} = 1.23$.   L-66600

Model C; $\frac{e}{c} = 0.82$.   L-67573
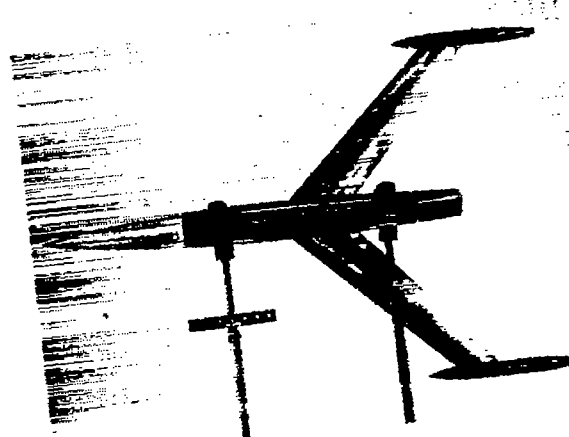
Model D; $\frac{e}{c} = 0.48$.   L-68749
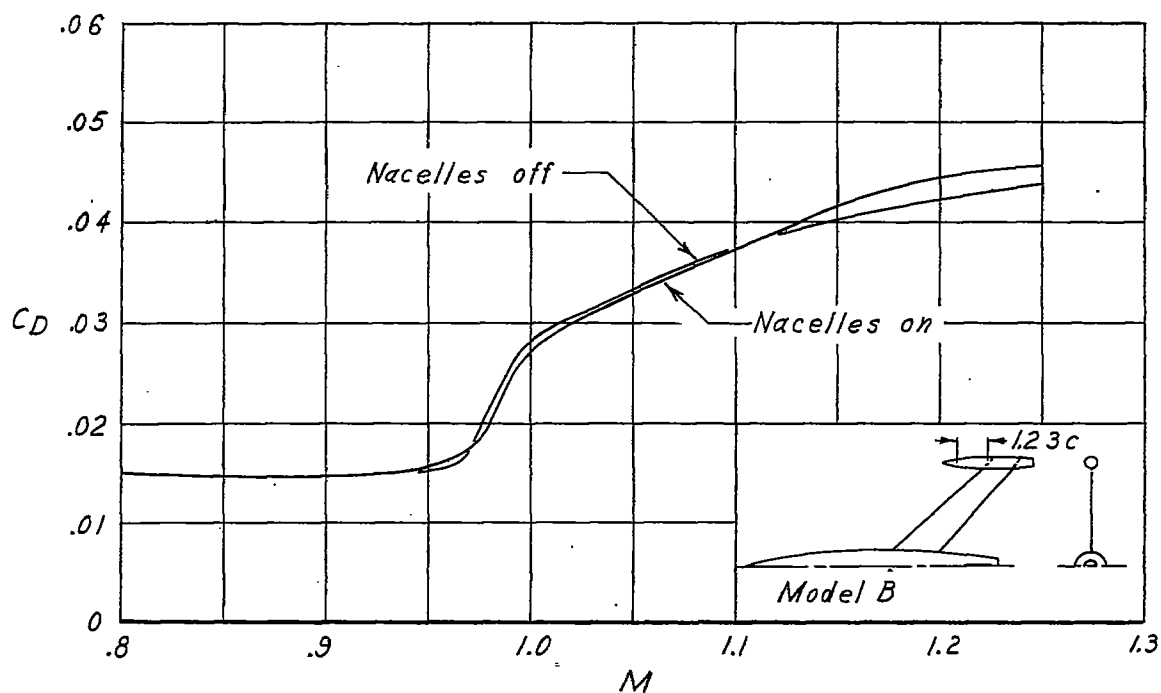
(b) Test models with nacelles.

Figure 3.- Concluded.
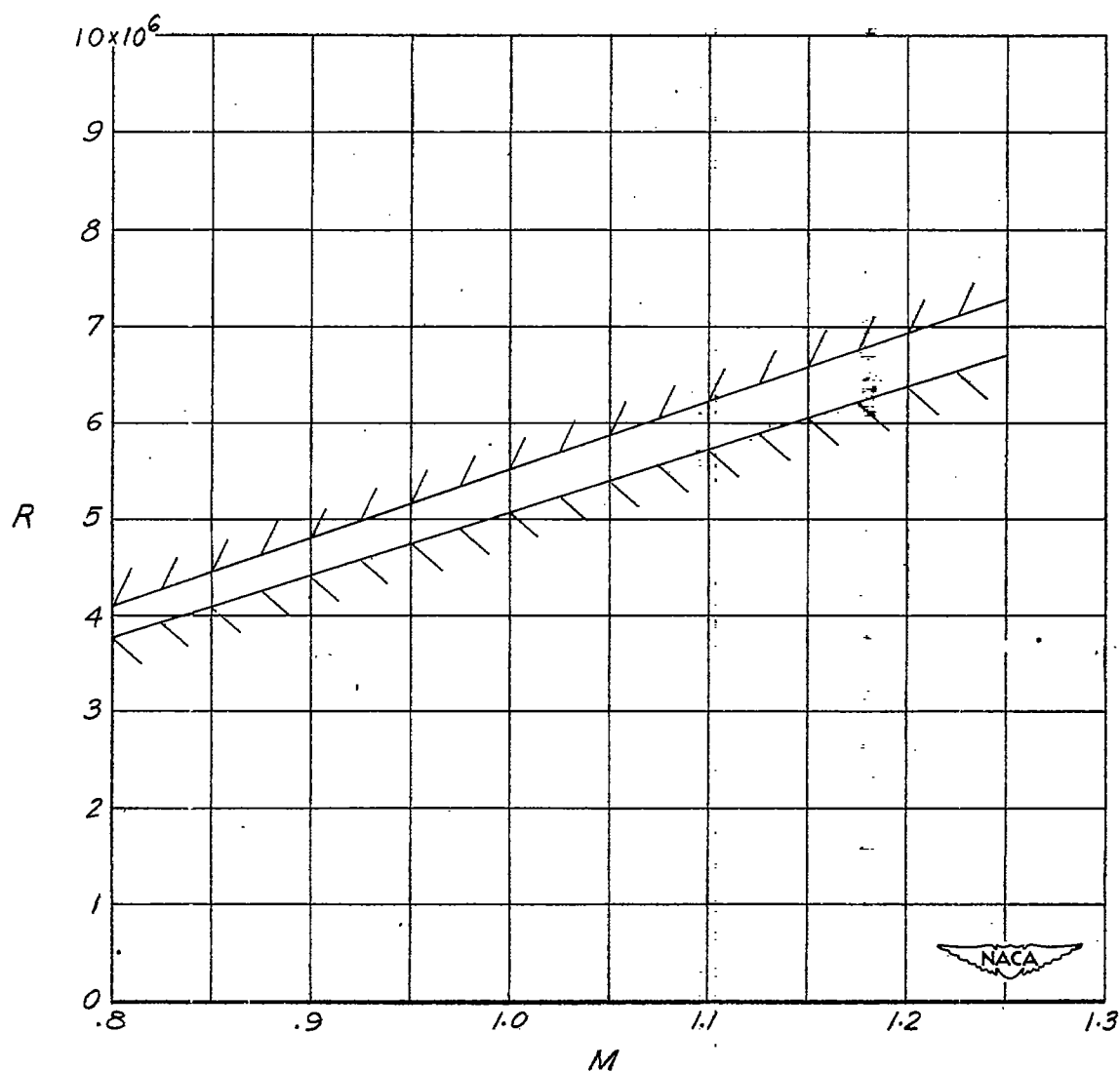
Figure 4.- Variation of Reynolds number with Mach number for models tested. Reynolds number based on wing mean aerodynamic chord.
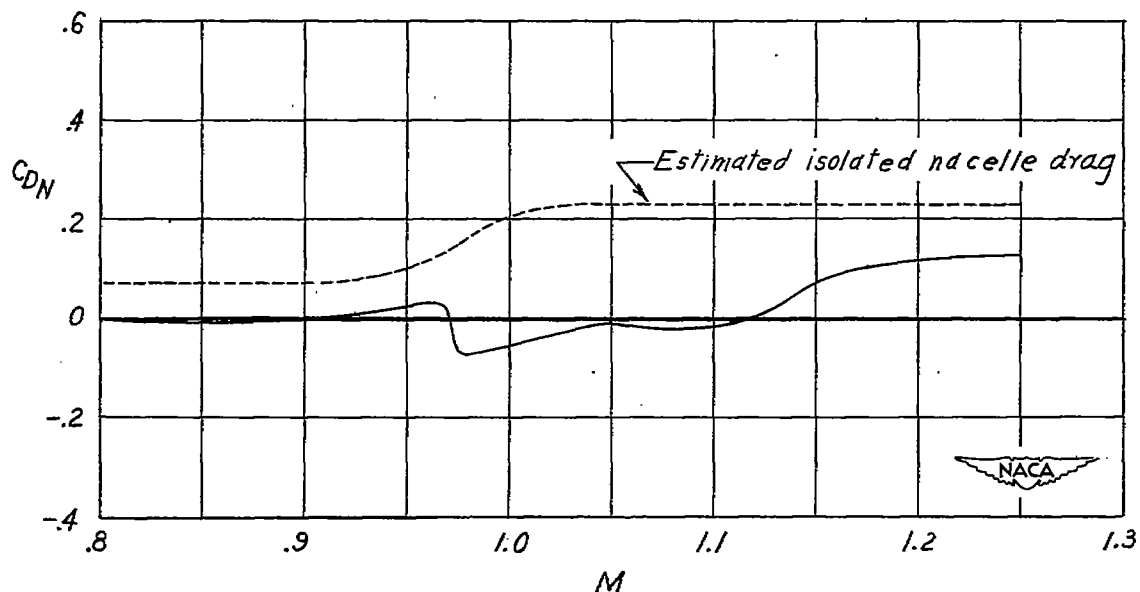
(a) Wing-tip nacelles at 1.23c.

Figure 5.- Variations of total drag, wing-body drag, and nacelle drag
coefficients with Mach number for nacelles located at 96 percent of
the wing semispan.
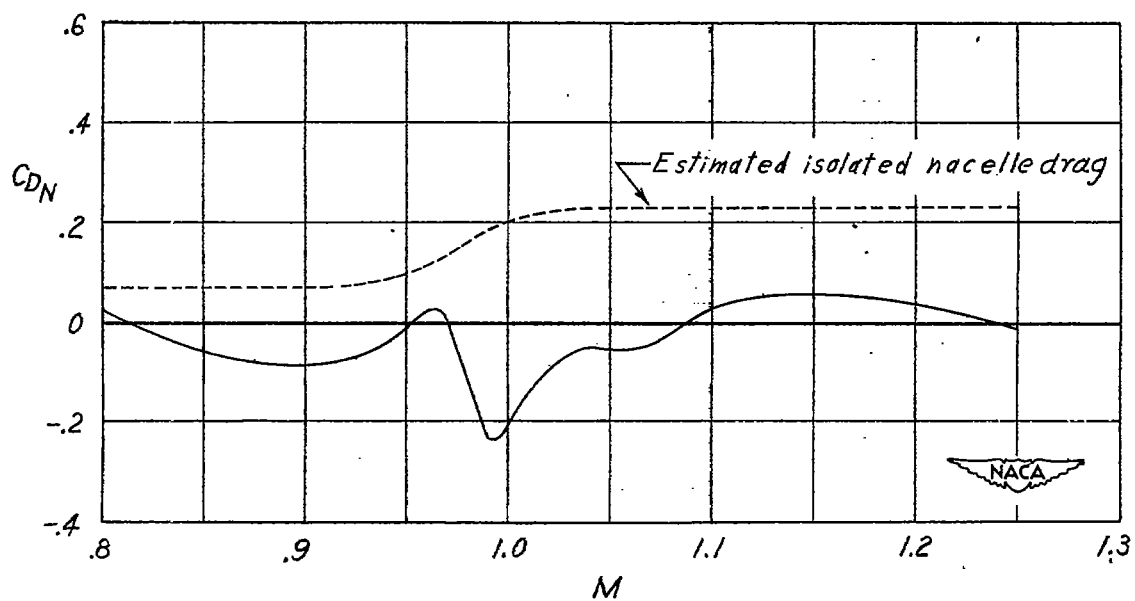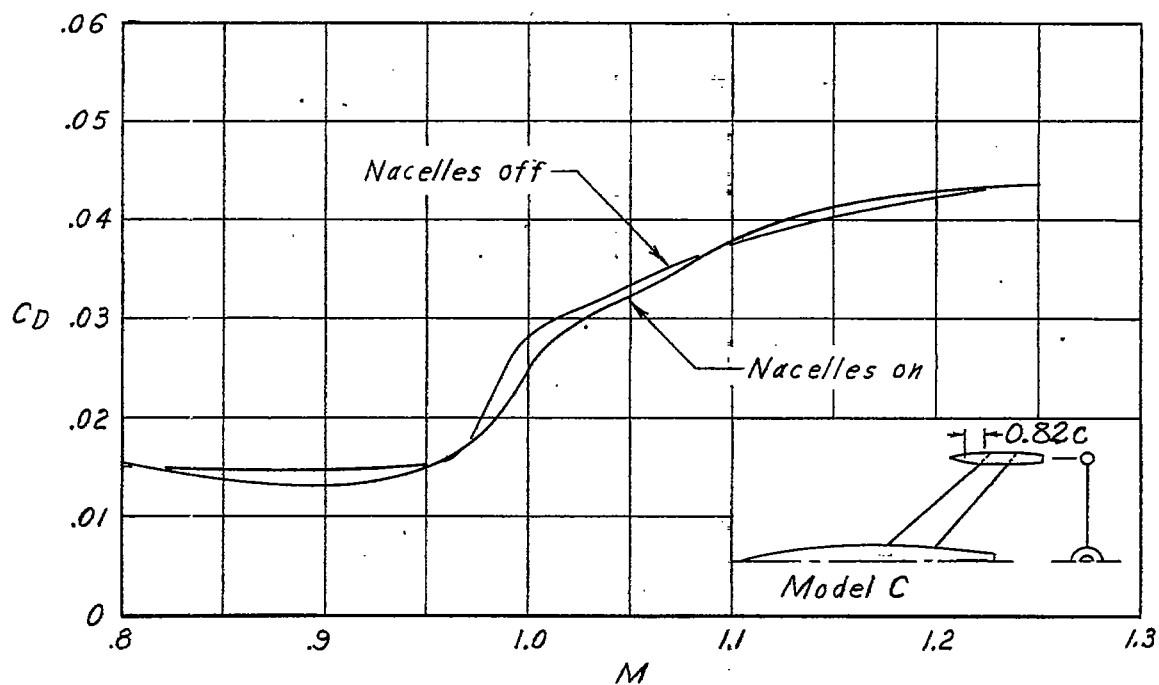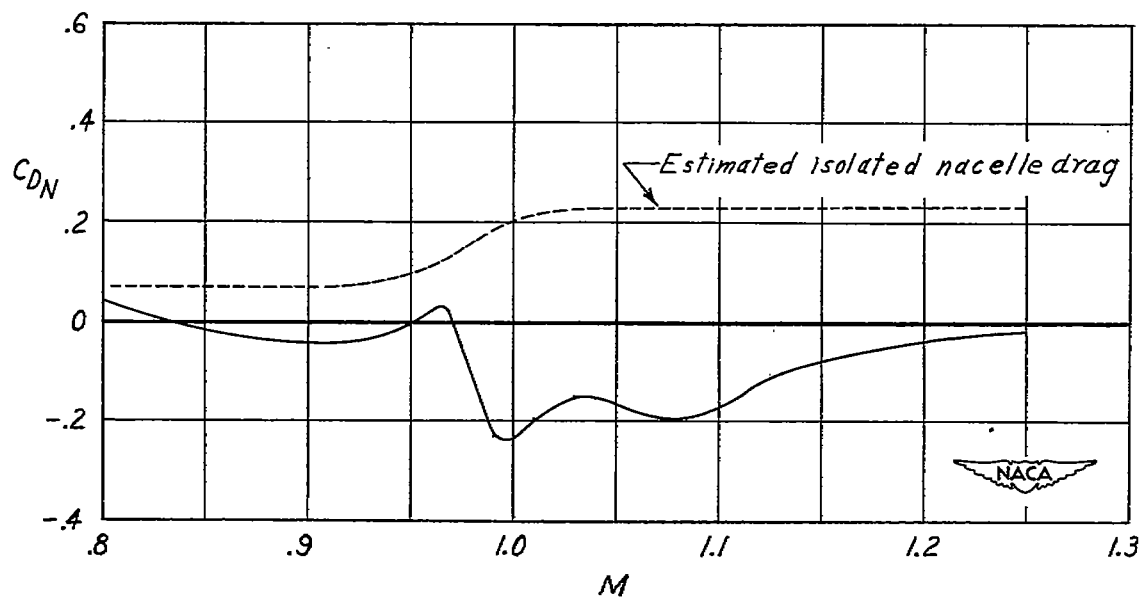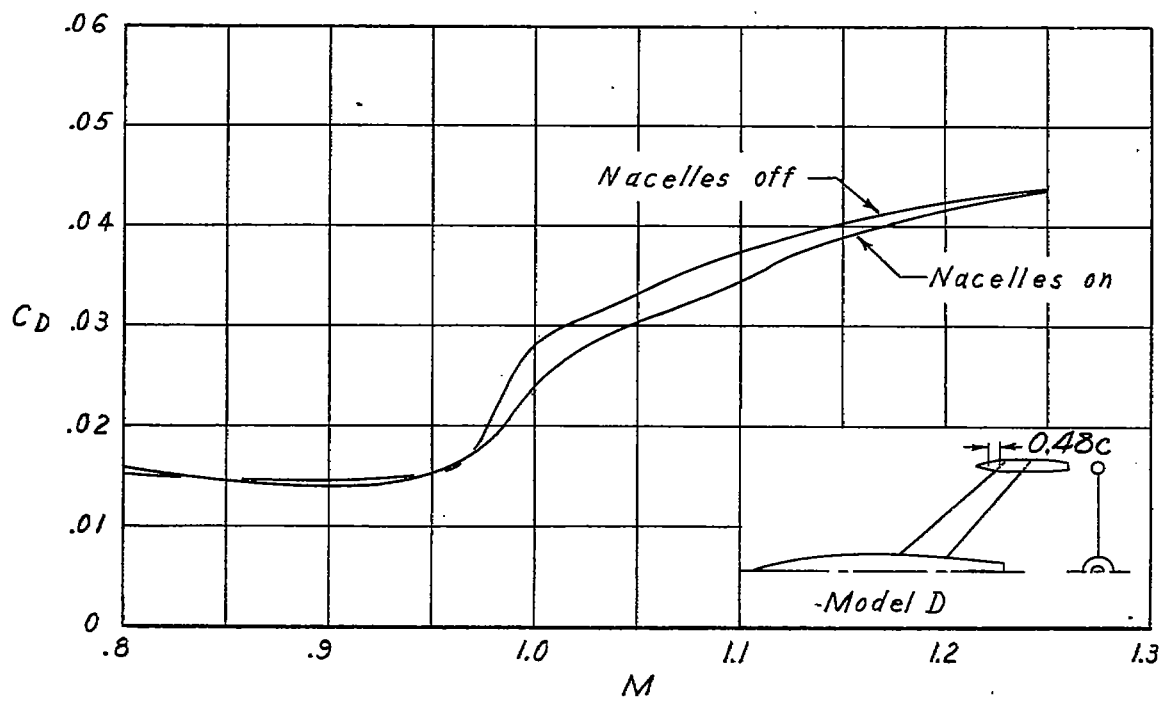
(b) Wing-tip nacelles at 0.82c.

Figure 5.- Continued.

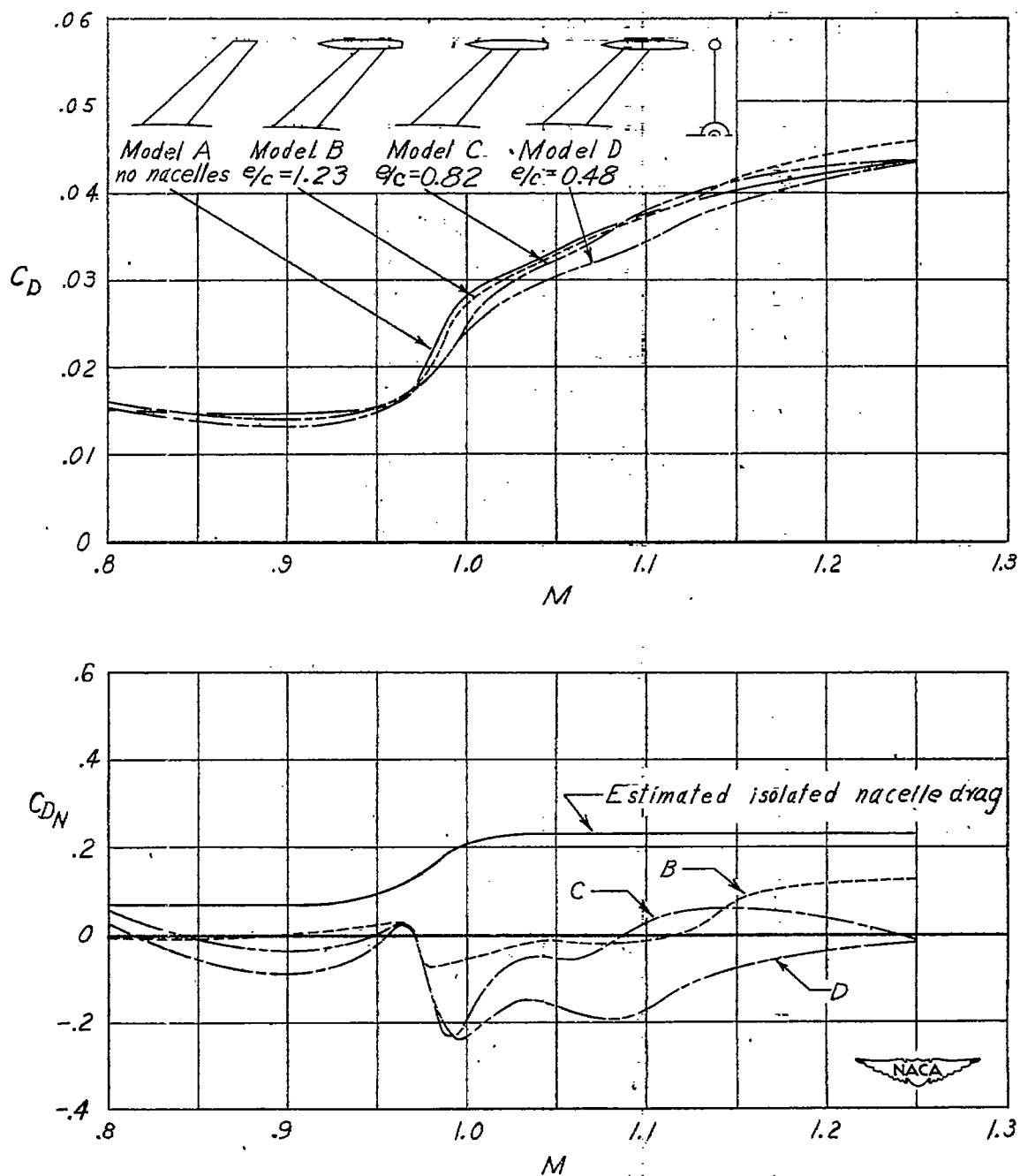(c) Wing-tip nacelles at 0.48c.

Figure 5.- Concluded.

Figure 6.- Comparison of total drag, wing-body drag, and nacelle-plus-interference drag coefficients with Mach number for nacelles located at 96 percent of the semispan.